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Psychological Monographs: General and Applied

The Effect of Varying Amounts and Kinds of Information As Guidance in Problem Solving

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I. INTRODUCTION

A PROBLEM may be said to exist when habitual responses fail to lead to the attainment of a desired goal. A search for a new response must then be undertaken. In intellectual problems, the problem solver must not only search for possible alternative courses of action, but must also select from among these alternatives the ones that will most successfully remove the obstacle to the goal. The search, then, is for information that will give structure to the problem. Presumably, as the amount of information developed is increased, the necessity for search is reduced. And, when all relevant information for the problem is available and understood, a *problem* no longer exists, although practice may still be required to make the new response habitual.

Information may be developed by the problem solver's own motivated search, or it may be made available to him. Information supplied by directions, by clues, or by other guidance, however, may vary in amount. There may be a greater or lesser reduction in the number of alternatives which remain to be discriminated.

If little or no information is supplied, the problem solver may fail to develop the primary information needed. This failure, in turn, may lead to frustration and a turning away from the problem. It has been shown that, left to their own devices, problem solvers often set up false assumptions which make for unnecessary restrictions that delay or prevent solution (14). Those who argue the efficacy of specifically directive guidance, point to the large amount of time expended in the discovery of the required information, with the important risk of the development and perseveration of errors (21, p. 147).

On the other hand, by presenting large and significant amounts of information, the necessity for search on the part of the problem solver may be lessened. The opportunity for a thorough examination of the problem may thereby be restricted. Situations have been described in which specific directive information was accompanied by failure to solve problems like those on which the guidance had been given (9, 12, 23). This lack of transfer has been explained as a failure of the solver to become cognizant of

[1] This study is a revision of a dissertation submitted in 1954 to the faculty of Teachers College, Columbia University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The writer is deeply indebted to Dr. Irving Lorge, who directed the dissertation, for his sustained interest, encouragement, and stimulating counsel. The writer also wishes to express his appreciation to Drs. Robert Thorndike, Herbert Solomon, and Lincoln Moses for their many helpful suggestions.

relationships among the structural elements of the problems studied. Information supplied in guidance, it has been suggested, should provide an opportunity for discovery of these relationships by the problem solver through his own motivated efforts, rather than anticipate such discovery by the identification of specific methods or principles (9). While in "discovery" more errors may occur, it has been felt that, in the context of a more intense search, such errors would not be deleterious (19).

Faced with two seemingly contradictory points of view, those charged with the guidance of learning experiences in problem solving are asked to choose between two unattractive alternatives in determining how much information to provide. It is the purpose of this monograph to re-examine the effects of giving varying amounts of information in the guidance of problem solving.

II. Rationale for an Experiment

If problem solving (as distinguished from routine drill) involves the search for a new response, then some "discovery" will accompany the successful solution of any problem. As Stroud has observed:

> The case for discovery is difficult to evaluate, and indeed cannot be evaluated until the term is given precise definition. There is discovery with help, much or little, and discovery without help. In a sense any act of understanding is a discovery no matter by how much help or explanation the understanding is achieved . . . (20, pp. 582-583).

It follows that, while the extent of search may be more or less restricted, any test of the effectiveness of varying amounts of information given as guidance would require that, as an experimental condition, *all* subjects (*S*s) be engaged in discovering a correct response. In many of the experiments which have been taken as supporting the desirability of methods of tuition emphasizing "discovery" the comparisons have been between groups who have been shown a correct solution and groups who must discover such a solution (9, 13, 19). Such studies are more correctly interpreted as giving additional support for methods of tuition emphasizing "understanding" rather than methods of routine drill. The question to be answered, however, is whether "understanding" itself, as measured by success in transfer, is enhanced by greater or lesser amounts of information given as guidance.

A distinction must also be made between "amount of information" and "number of clues." It would be possible to design an experiment in which contrasted groups receive varying numbers of clues. The clues, moreover, might differ in the amount of information each made available (that is, in the extent to which the *S* was enabled to discriminate between possible alternative courses of action) (4). Whatever the discrimination permitted by the least explicit of the clues, this discrimination would also be made with each additional and more direct clue. The effect of such repetition would be to reduce errors and increase understanding quite apart from the fact that with each additional clue, additional information might be provided. It would follow that, where the effectiveness of differing amounts of information is the focus of interest, a necessary experimental control would be that the information any particular *S* receives be the same information at each repetition of clues, and that the number of repetitions be the same for all *S*s.

A number of experiments have been reported where the two experimental

safeguards described above were given consideration. Typically, in these studies, *S*s given a general principle, underlying a related cluster of problems, were less successful than were *S*s whose attention was simply called to certain structural features of the problem situations (5, 12, 16, 22, 23). Since the application of the generalization should lead directly to solutions, these results have also been taken as supporting evidence for the superiority of methods of tuition allowing for greater search and "discovery." But an alternative explanation is possible which would take account of the observation that information may differ in kind as well as in amount.

Duncker has suggested that problems are usually attacked in stages, the solver setting up a series of subproblems (5). Protocols of problem-solving experiments would indicate that, while a few individuals may begin by trying to discover a generalization which may, when found, be applied to all variations of the problem, the more typical process is to attempt first to discover a method of attacking and solving specific examples (6, 18). Generalization may or may not follow success with a number of problem variations. If this is so, then the greater effectiveness of information related to a method of attacking specific examples of a problem-type may be explained as arising not from any inherent difference in the awareness or activity demanded of the *S*, but from the appropriateness of the information to the task the problem solver has set himself. Information given about the principle involved may be quite inappropriate in the early stages of problem solving.

If guidance toward the discovery of an attack on a problem (method information) and information about a general principle underlying a cluster of similar problems (rule information) are, in fact, two *kinds* of information relating to two different aspects of problem solving, then not one, but two, criteria of success of guidance would be indicated; viz., success in solving the problems, and success in verbalizing the rule. Where the information made available is appropriate to the criterion used, then the guidance should prove beneficial. Where the information is inappropriate, guidance should prove ineffective, if not actually detrimental.

Further, if information about rule and about method are two kinds of information, it is possible to envisage guidance that would make available to the student greater or lesser *amounts* of either kind of information. If the measure of effectiveness is appropriate to the kind of information made available, and if the less explicit information proves more effective, then additional support would be given to the position that opportunity for greater self-directed search by the student is desirable as guidance. If, on the other hand, the more explicit information proves more beneficial under these conditions, then the inference would be that greater and more direct help is superior.

To argue that understanding how to solve a problem and understanding the principle underlying the solution may be independent does not imply that both understandings may not be acquired and integrated. Given a limited period of time in which to learn to solve a type of problem, the *S* with superior intellectual ability would be more likely to accomplish such an integration.

In summary, then, the desirability of making available lesser as against greater

amounts of information in the guidance of problem solving has been a disputed question. Many of the experiments which have been interpreted as arguing for the efficacy of lesser amounts of information are more correctly interpreted as comparing methods involving problem solving as against methods of routine drill. There are other experiments, however, where all *S*s were engaged in the discovery of the solution, and where lesser amounts of information proved more beneficial than did greater amounts. One possible interpretation of these results is that there is an advantage accruing to the *S* when the opportunity for search is not restricted. An alternative explanation has been suggested which would attribute the failure of the more explicit information to the inappropriateness of the kind of information presented.

III. An Experiment

Hypotheses

To test the effectiveness of varying amounts and kinds of information as guidance in problem solving and with due regard for the argument above, a number of hypotheses were formulated.

It was predicted that only information appropriate to the criterion employed to evaluate success would be effective as guidance. Specifically, where the criterion was the *S*s' success in solving problems, both instructional and transfer, only information about the method of attacking specific examples would prove effective. Conversely, where the criterion was success in verbalizing a principle, only information about the principle would prove helpful. In addition, it was hypothesized that, where the information was inappropriate to the criterion employed, no significant effects would be discerned as a result of the guidance.

It was further hypothesized that, given an appropriate criterion, the effectiveness of the guidance would increase directly as the amount of information supplied the *S* increased. That is, where the solution of problems was the criterion measure, the more information given about the method of attacking instructional examples, the more successful the *S*s would be. Similarly, where stating the rule was the criterion, the more information about the rule which was given as guidance, the more often the principle would be correctly generalized.

Finally, it was hypothesized that the effects of the varying kinds and amounts of information would be similar for *S*s of higher and lower intellectual ability.

The Instructional Tasks

To test these hypotheses a problem was required which met certain conditions: (*a*) the problem had to be one with which most *S*s would not have had prior experience; (*b*) the problem had to be susceptible to numerous variations; and (*c*) all of the variations had to be solvable by the application of a common principle. The "match-task" described by Katona (9) met these three conditions. An example of this problem-type is shown in Fig. 1.

The directions which accompany the problem shown in Fig. 1 are: "The lines in the drawing represent matches. They have been arranged so that there are five squares in the drawing. Can you make four squares out of the five by moving no more than three matches?"

There are four restrictions which must be observed in solving the problem: (*a*) all of the squares in the answer must be of equal size; (*b*) all of the squares in the

answer must be closed; (*c*) all of the matches must be used in the answer; and (*d*) all of the sides of the squares in the answer must be only a single match in thickness.

It will be noted that there are 16 matches in the example. Since four squares are required, it follows that no match can serve as the side of more than one square in the answer. Matches must be moved, therefore, so that no match serves such a double function. This is the principle common to all variations used in the present experiment.

The principle is not a formula in the sense that knowledge of it will give the *S* an automatic understanding of which matches are to be transposed in any given variation of the task. Moreover, as Katona points out, solution of the task may be approached quite independently of knowledge of this rule. Solution of the problems may result from perceiving "holes" in the presentation figures. Since the number of matches which one is permitted to transpose is limited, successful solution will hinge on finding those squares which can be completely eliminated from the presentation drawing by the removal of the least number of matches. Knowledge of the principle presumably would help the student to identify these "critical" squares, but it is possible to solve the tasks without becoming aware either of the number of matches in the problem, or of the fact that solution depends on eliminating matches serving a double function. The rule does serve to limit the alternatives before the *S*, and should give the problem solver an important clue as to the appearance of a correct answer.

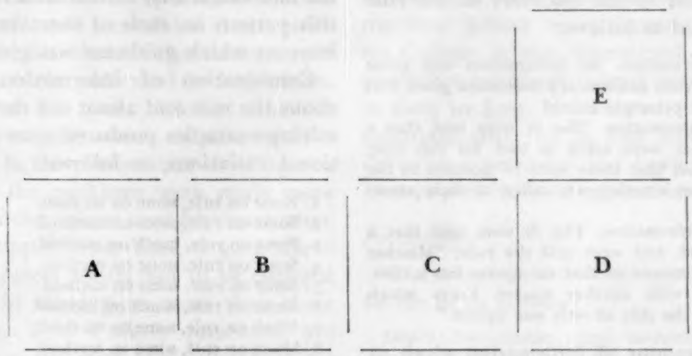

Fig. 1. Sample of Katona match task.

The task shown in Fig. 1 was used as a pretest to screen out *S*s with prior knowledge of the problem. The *S*s were also asked to indicate whether they had ever seen the problem, or ones like it. Those who responded in the affirmative, and who solved the trial problem, were eliminated from the experiment.

Three tasks were used as instructional problems. The first of these was a simple inversion of the puzzle shown in Fig. 1; the square E of that drawing being presented below, rather than above, square D. The second of the instructional tasks represented only a slight modification; square E of Fig. 1 was shifted to a posi-

tion above square B. The last of the three instructional tasks was a somewhat more difficult drawing; square A of Fig. 1 was shifted to a position above square B so that the five squares of the presentation drawing formed a U.

The Instructional Variations

The amount of information given as instruction to the discovery of the rule was varied as follows:

No information. No information was given about the rule, nor was any indication given that a common principle existed.

Some information. The *Ss* were told that a rule existed, were asked to look for this rule, and the fact that there were 16 matches in the presentation drawing was called to their attention.

Much information. The *Ss* were told that a rule existed, and were told the rule: "Matches should be moved so that no square has a common side with another square. Every match should be the side of only one square."

The amount of information given as guidance to the discovery of the method of solving the examples was also varied in three ways:

No information. No information was given.

Some information. The *Ss* were directed to shade in certain of the squares, and their attention was called to the fact that four matches remained which were the sides of unshaded squares. The clue has the effect of calling attention to the critical squares.

Much information. For the three tasks used for instruction the *Ss* were told which matches to move where, and were asked to practice this solution.

The clues called "some information" were similar, both in the context of a search for the rule and for the method, in that the *Ss'* attention was called to the structural relationships inherent in the tasks. The clues designated "much information" made available highly explicit guidance and reduced the necessity for an intensive search of the problem by the *S*. At no point, however, was a completed solution of any task shown to any *S*. Every student had to discover a correct response, but this discovery was with the aid of more or less direct help from the instructions.

In combining information about rule and method, the following pattern was adhered to: (*a*) a statement of the task to be solved, (*b*) information about the rule, if any, and (*c*) information about the method, if any. Instructions followed this pattern on each of the three problems on which guidance was given.

Combination of information given about the rule and about the method of solving examples produced nine instructional variations, as follows:

1. None on rule, none on method.
2. None on rule, some on method.
3. None on rule, much on method.
4. Some on rule, none on method.
5. Some on rule, some on method.
6. Some on rule, much on method.
7. Much on rule, none on method.
8. Much on rule, some on method.
9. Much on rule, much on method.

Thus, the instructional variations represented a systematic increase in the amount of information made available to the *S* from a treatment in which the students were given no information at all to one in which highly directive information was given about both the rule and the method.

The trial problem, a page illustrating and explaining the restrictions, and the three instructional problems (each on a separate page) were developed into an Instruction Booklet to facilitate group administration of the experiment (3). There were nine variations in the practice booklets, each representing one of the alternative treatments described above. The combination of information on rule and method that any particular *S* received was the same for each of the three instructional problems the *S* received. The presentation of each task

was accompanied by a space in which the *S* could make provisional tries, and also an answer column in which he could indicate the matches to be transposed in each problem, and could make a drawing of the answer if it had been discovered.

The Test Problems

Eight additional variations of the match task were formulated as test problems. The first three of these were simple reversals of the tasks used for instruction. The final five tasks differed either in that triangles were substituted for squares in the presentation drawings, or in that the problems were made more complex than those used for instruction. For example, Test Task 6 gave the *S* seven squares which had to be changed to five by moving no more than three matches. Test Task 7 presented five squares in the form of a Swiss cross; the compactness of the drawing seemingly creating special difficulties.

Thus, two measures of transfer were provided. These measures will be identified as "simple transfer" for the three reversal test problems, and "complex transfer" for the remaining test tasks.

Finally, a page was given the *S* on which to write a verbalization of the principle common to all variations of the match task which he had encountered.

The test problems and the final page for writing the rule were brought together in a Test Booklet, completely independent of the various Practice Booklets (3).

The Subjects

The materials were administered to 255 twelfth-year students whose median age was 17 years, 3 months. Five students were eliminated on the basis of prior acquaintance with the tasks. An additional 17 students were absent when the measure of mental ability was secured and were not included. The remaining 233 students represented ten classes in eight high schools in New York and New Jersey suburban communities. A wide variation existed in the facilities provided by these eight schools. Based on information made available by the Metropolitan School Study Council, Teachers College, it was determined that expenditure per pupil ranged from as low as $165 to $495. It seems a tenable assumption that the *S*s had had widely different experiences and types of guidance in problem-solving situations.

Procedures

The two booklets were administered to the *S*s as follows:

Step 1: Introduction (three minutes). The instruction booklets were distributed randomly within each class. After the students filled in background data, an explanation of the purpose of the experiment was read. The *S*s were told that neither their intelligence nor ability was being tested and that the results of the experiment would not affect their school grades, but that the experimenter was seeking information on how students learned to solve problems.

Step 2: Trial problem (one minute). Students were asked to attempt the trial problem. At the end of one minute, students were asked to write "Yes" if they had ever seen the specific task or problems like it before; "No" if the problem was new to them.

Step 3: Explanation of restrictions (two minutes). The restrictions were read aloud. Students were then asked to study illustrations of the improper solutions. At the end of two minutes, they were informed that they could look back at the page of restrictions during the remainder of the practice period. This statement was repeated twice during the instruction period.

Step 4: Instruction period (twelve minutes). The students were told that they would have twelve minutes, that they could work at their own best speed, and that they could divide the instruction period between the three tasks as they thought best. Finally, they were informed that since all of the instruction booklets were different, they would not be doing the same thing as other students around them. At the end

of the twelve minutes all instruction booklets were collected. No questions were answered during the instruction period.

Step 5: Test period (sixteen minutes). After the test booklets were distributed, students were informed that they would have sixteen minutes to solve as many of the eight test problems as they could. Again, they were told to work at their own best speed, and to divide the test period among the problems to suit themselves. No questions were answered.

Step 6: Writing the rule (three minutes). At the conclusion of the test period, students were told that they would have three minutes to formulate a rule. They were instructed that they might look back at the test problems they had attempted if this would help them formulate a rule.

With the exception of the trial problem, no attempt was made to assure equal time being spent on each of the tasks. Rather, only the total time assigned to the instruction period, to the test, and to the writing of the rule, was controlled. Experience in preliminary tryouts of the material indicated that withdrawing incomplete tasks was disturbing. Many students abandoned the problems after several had been removed in this fashion. The arbitrary decision to control the total block of time, rather than time spent on each problem, while creating some additional difficulties in the analysis, seemed preferable since a major source of frustration for many students was reduced. More importantly, to have withdrawn the tasks would have penalized most those groups given the least amount of information as instruction.

Test of Mental Ability

All *S*s were given Form A of the Otis Self-Administering Test of Mental Ability, Higher Examination (16). The test publishers report a reliability of .92, using comparable forms. The twenty-minute score on this test was employed as an indicator of the *S*s' mental ability. This measure is best thought of as a power score, involving both speed and level of ability (1). The use of time limits during both the instruction and test periods argued for the use of this score as the control of initial ability rather than the untimed Otis score.

Students scoring 45 or better on the Otis were designated as "Highs," or higher than average in mental ability (the mean score for all *S*s was 45.3) and those scoring 44 or lower were called "Lows," or lower than average in mental ability.

IV. Results of the Experiment

Number of Students

The number of students receiving each of the nine variations in instructions on the match task was not exactly equal, as shown in Table 1. However, when tested against the marginal totals, the number of students given each form of instruction did not prove to be disproportionate. For this reason it was

TABLE 1
NUMBER OF STUDENTS RECEIVING VARYING KINDS AND AMOUNTS OF INFORMATION AS INSTRUCTION

Information about the Rule		Information about the Method			Totals Rule
		None	Some	Much	
Much	Highs	12	15	11	38
	Lows	16	10	14	40
Some	Highs	18	14	13	45
	Lows	8	12	16	36
None	Highs	13	12	14	39
	Lows	11	11	13	35
Totals Method	Highs	43	41	38	122
	Lows	35	33	43	111

Tests for hypothesis that cell frequencies are proportional: Highs: $\chi^2=2.5$; Lows: $\chi^2=3.9$; χ^2 .05, 4 $df=9.5$.

possible to make comparisons of the effectiveness of the varying amounts of information with assurance that the comparisons would not be unduly affected by the existence of unequal numbers in each of the treatment groups.

Mental Ability

An analysis of variance of the mean mental ability scores for the nine treatment means did not provide a basis for rejecting the null hypothesis for either the more or less capable students. In the comparisons which follow, therefore, it was possible to infer that mental ability had been equated for the groups receiving each of the instructional variations.

Instruction Problems

The students were given twelve minutes to attempt the three instruction problems. Since the time the students spent on each of these problems was not controlled, the possibility existed that the students would attempt different numbers of the problems, depending on the kind and amount of information made available to them as guidance. To test this possibility, the mean number of instruction problems attempted was computed for each of the variations. The "number of problems attempted" was defined as the number of the last of the three problems on which some evidence was present that the task had been considered by the student (sketch lines, doodling, etc.).

The analysis of the differences among these means was accomplished by the application of distribution-free tests of significance. These tests were employed to avoid making untenable assumptions both about the normality of the underlying score distributions and the homogeneity of treatment variances. These procedures, as adapted, were used throughout the remaining analysis, and are discussed in Appendix A.

When these tests were applied, significant differences in the number of instruction problems attempted were found to exist, attributable to the amount of information the student received about the method. Among the students of higher ability, as the explicitness of the information offered about the method increased, the number of instruction problems attempted also increased. Among the students of lower than average ability, however, while the students who received "some" or "much" information attempted more tasks than did students who received no information, the difference between those for whom the form of help was "some" rather than "much" was not reliable.

No significant differences in the number of instruction problems attempted could be discerned arising from variation in the amount of information the students had received about the rule. Nor did the fact of having received a certain combination of rule and method information result in significant differences in mean number of instruction problems attempted.

To take account of these differences in the number of instruction problems attempted, in analyzing success in solving the instruction tasks, the percentage of those problems attempted which were solved correctly was computed for each of the treatment groups. These percentages are given in Table 2.

The instruction problems (and the transfer problems as well) were scored as either right or wrong. To be credited with having solved the problem, the student had to indicate both a correct

TABLE 2

PERCENTAGE OF INSTRUCTION PROBLEMS ATTEMPTED WHICH WERE SOLVED BY STUDENTS RECEIVING VARYING KINDS AND AMOUNTS OF INFORMATION AS INSTRUCTION

Information About the Rule		Information About the Method			Totals Rule
		None	Some	Much	
Much	Highs	21	58	90	59
	Lows	13	55	65	44
Some	Highs	23	53	90	57
	Lows	00	47	45	40
None	Highs	39	74	86	69
	Lows	09	50	77	51
Totals	Highs	28	61	88	61
	Lows	10	51	62	42

Differences attributable to kind of information received

Kind of information	df	χ^2		
		Highs	Lows	.05
Method information	2	18.0	14.4	6.0
Rule information	2	1.7	8.4	6.0
Method × rule information	4	4.0	2.8	9.5

Differences attributable to amount of information received

Comparison	*U* Test			
	Method		Rule	.05
	Highs	Lows	Lows	
Much—no information	3.6	3.6	.0	2.0
Much—some information	2.5	1.4	.4	2.0
Some—no information	2.5	3.3	−1.1	2.0

set of matches to be transposed, and had to make a drawing of the required figure corresponding to the matches marked for transposition.

There were instances in which the student showed a satisfactory answer drawing without marking a correct set of matches to be moved, and the opposite sometimes occurred. In the majority of cases, however, the two parts of the answer were either both correct or both incorrect. This dependence argued against the use of partial scores. The use of a simple right or wrong score introduced less chance error, since it was not necessary to determine whether the movement of the "critical" matches represented an accidental event or indicated some partial understanding of the task.

For students of higher than average mental ability, the percentage of instruction problems solved increased as the amount of information made available to them about the method was increased. Students given no information about the method attempted and solved fewer of the tasks than students given some information, and these, in turn, attempted and solved fewer problems than students given the greatest amount of information about the method.

For students of less than average ability, differences in the percentage of the instructional tasks solved also accompanied the proffering of information about the method of attacking the examples. For these students, however, no one-to-one correspondence was established between the amount of information presented about the method and the percentage of tasks solved. Giving the less able students information resulted in an increased number of instruction problems attempted and solved, but making available highly directive information did not prove to be substantially superior to giving less explicit clues.

For both the more and the less able students, making available information about the rule underlying the tasks did not result in significant differences in the percentage of the problems solved. If anything, information about the rule re-

sulted in fewer problems being correctly solved. Among students both above and below average in ability, the groups given no intimation that a rule existed, and not told the rule, solved more of the problems than did those who received this information, although the differences were not reliable. The detrimental effects of information about the rule appeared to be somewhat more marked among the less able students.

No significant effects were found in the percentage of instructional tasks solved which could be assigned to the students having been given a particular combination of information about the rule and method.

Simple Transfer Tasks

The first three test problems were simple reversals of the tasks which had been used for instruction. All of the reversals were attempted by all but seven of the students, and these seven were distributed among the treatment groups. The three problems provided a measure of "simple" transfer, since a direct application of the solutions discovered during the instructional period was possible. The mean number of simple transfer problems solved correctly is reported in Table 3.

Differences in the number of simple transfer problems solved were found which were attributable to the amount of information about method which the student had received. For both students above and below average in ability, the effect of having been given some information about the method was to increase the number of simple transfer problems solved. For the more capable students the number of problems correct increased as the amount of information which had been made available increased, although only the difference between the group of students given the most explicit form of information and the group given no information was reliable. For the less able students, on the other hand, the students who had been given the less direct clues solved most of

TABLE 3
MEAN NUMBER OF SIMPLE TRANSFER PROBLEMS SOLVED BY STUDENTS RECEIVING VARYING KINDS AND AMOUNTS OF INFORMATION

Information About the Rule		Information About the Method: None	Some	Much	Totals Rule
Much	Highs	1.5	2.5	2.0	2.0
	Lows	.4	1.4	.9	.9
Some	Highs	.9	1.5	2.6	1.7
	Lows	.0	1.0	.6	.5
None	Highs	1.6	1.7	1.9	1.7
	Lows	.5	1.3	1.7	1.2
Totals	Highs	1.3	1.9	2.2	1.8
	Lows	.3	1.3	1.0	.9

Differences attributable to kind of information received

Kind of information	*df*	χ^2 Highs	χ^2 Lows	.05
Method information	2	8.4	14.0	6.0
Rule information	2	1.2	9.7	6.0
Method×rule information	4	10.7	9.4	9.5

Differences attributable to amount of information received

Comparison	*U* Test: Method Highs	Method Lows	Rule Lows	.05
Much—no information	2.1	2.4	−1.1	2.0
Much—some information	.9	−1.0	1.2	2.0
Some—no information	1.8	3.4	−1.8	2.0
Much+some—no information	2.2	3.4	−1.7	2.0

the problems, although the differences between the two groups given some form of help were not significant. Thus, the high ability students were helped most by the more direct information, while the less able students did not find such help more effective.

Having had varying amounts of information made available about the rule did not result in any substantial differences in simple transfer. While the differences attributable to the three amounts of information given about the rule were not in themselves reliable, the order of performance is of some interest. Among the high ability students, those given a statement of the rule solved more of the simple transfer problems than those not given the rule. Among the less able students, those *not* given the rule or a clue to the rule, solved the most problems.

For the students of less than average ability there was no significant effect resulting from having been given a particular combination of information about both rule and method. Such an effect was present in the performance of the more able students. To evaluate this interaction between the two kinds of information among the more able students, the percentage of correct solutions was determined for each treatment group.

Compared to the group of students who had received no information either about the rule or the method, the two treatments in which the student received an explicit clue in combination with a less explicit clue were significantly superior. Thus, being told the rule but receiving only a clue to the method, or being given directive information about the method with only a clue to the rule appeared to be highly effective forms of guidance for the more able students. None of the other combinations of information about both rule and method resulted in a performance on the simple transfer problems substantially different from the treatment in which the student received no guidance at all.

The first three test problems were very directly modeled on the problems used for instruction, and it has been shown that there were significant differences in the number of instruction problems attempted and solved. The question arose, therefore, as to what the effects of the treatments would have been on success with the simple transfer tasks if all students had solved a similar number of instruction problems.

Since success on both the instruction and simple transfer problems was affected by the treatments, to adjust the transfer scores for the instruction problem scores would have resulted in removing part of the treatment effects. But if an adjustment were made, and there still remained significant differences attributable to the treatments, then the interpretation would be that not all of the differences on the transfer problems are explainable in terms of the number of instruction problems attempted and solved (2, p. 82f). The inference would be that there were effects arising from the variations in the amount and kind of information quite apart from the percentage of problems solved during the instruction period.

The adjustment was appropriate only for the students of higher than average ability, since only for this group could the hypothesis of no linear regression between the two measures be rejected.

No reliable differences in the means of the treatment groups remained once

the simple transfer scores had been adjusted for percentage of instruction problems solved. It may be inferred that, for the students of greater ability at least, there were no effects resulting from having been given varying kinds and amounts of information as guidance, apart from those which could be explained by the fact that differences existed in the number of instruction problems attempted and solved.

Complex Transfer Tasks

The final five problems of the test departed in form, though the principle underlying the solution remained the same, from the tasks which had been used for instruction. These problems permitted a second measure of transfer. Since these problems were less obvious variations of the instruction tasks, presumably the students whose initial experience with the match tasks had entailed the greatest search should have had some advantage on these problems.

By withdrawing the final task from the analysis, differences in the number of complex transfer problems attempted by the students in the various treatment groups were removed. On the four remaining tasks no significant differences were found in the number of problems attempted. (Using the subgroups described in Appendix A as replications, chi squares of 13.8 for "Highs" and 10.6 for "Lows" were obtained with critical value for chi square .05 equal to 15.5.) Means for the treatment groups on these four problems are given in Table 4.

TABLE 4

MEAN NUMBER OF COMPLEX TRANSFER PROBLEMS SOLVED BY STUDENTS RECEIVING VARYING KINDS AND AMOUNTS OF INFORMATION AS INSTRUCTION

Information About the Rule		Information About the Method: None	Some	Much	Totals Rule
Much	Highs	1.5	2.5	2.2	2.1
	Lows	.7	1.0	.7	.8
Some	Highs	1.1	1.3	2.7	1.7
	Lows	.6	1.1	.4	.7
None	Highs	2.0	2.3	1.3	1.8
	Lows	.4	1.7	1.4	1.2
Totals Method	Highs	1.5	2.0	2.1	1.9
	Lows	.6	1.3	.8	.9

Differences attributable to kinds of information received

Kind of information	df	χ^2: Highs	Lows	.05
Method information	2	6.9	11.7	6.0
Rule information	2	1.1	4.4	6.0
Method $\times$ rule information	4	10.7	10.7	9.5

Differences attributable to amount of method information received

Comparison	U Test: Highs	Lows	.05
Much—no information	1.5	.6	2.0
Much–some information	−0.5	−1.6	2.0
Some—no information	1.6	2.3	2.0
Much + some—no information	1.7	1.6	2.0

For the more capable students neither the variations in the amount of information about the rule nor about the method produced significant differences in the number of complex transfer tasks solved. Students given information about the method did solve more problems than students given no such information, but the differences in performance were not reliable.

Among the less able students, however, the students who had had the less explicit form of information about the method were successful in solving more of these tasks than were students given

no information about the method. The students given highly directive clues to the method did not differ significantly in performance on these problems from students given less explicit aid or those given no information at all.

Again, no substantial differences in performance on the complex transfer problems resulted from the student having been given varying amounts of information about the rule.

Among both the students of more and less than average ability the groups given no instruction about the method did better relatively, on the complex transfer problems than they had on either the simple transfer problems or on the instructional tasks. As a result, for these four complex problems it was not possible to conclude that the students given information about the method, either in the more or less explicit form, were superior to those given no information of this kind.

For both ability-classes of students, differences were found on the complex tasks resulting from the combination of information received as guidance about the rule and method.

Using the students who had received no information about either rule or method as a comparison group, two combinations of instruction were found to differ significantly among the more capable students. These were the group of students who had been given only a clue to the rule, and the group given only directive information about the method. Both of these groups solved substantially fewer of the complex problems that did the students given no help at all. Solving the greatest number of the tasks were the groups given direct information about the rule together with less explicit information about the method and vice versa, but these students were not so superior to those given no information at all that chance could be excluded as an explanation of the difference.

On the other hand, among the students of less than average ability, the groups given only a clue to the method, either in the direct or the less explicit form, and given no information about the rule, were superior. None of the other groups of students did significantly differently than the group given no information at all.

Thus, there was little relationship between the order of treatments among the high and low ability students. The students of lesser ability profited most when guidance consisted of information about the method alone, and when no mention was made of the rule. The better students, however, found these forms of help less effective, and were benefited by having received information about the rule in addition to information about the method.

Success on the simple and complex transfer problems was related and the hypothesis of no linear relationship could be rejected. The complex problem scores were adjusted for their regression on the simple transfer scores and the resulting means were compared. No reliable differences in the number of complex problems solved by the various treatment groups remained once this adjustment had been made. Since the adjustment removed part of the treatment effects, the failure to find differences may best be interpreted as indicating that no effects, beyond those explained by the differences in the number of simple transfer problems solved, were present. Thus, success on the more difficult transfer problems was explained by prior success on the simpler tasks. And,

as has been shown for the better students at least, success on the simpler transfer tasks was associated with the students having solved a greater number of the instructional problems.

Writing the Rule

As their final task, students were allowed three minutes in which to write a statement of the principle involved in the problems they had attempted. They were permitted to look back over their work on the match tasks to help formulate this rule.

A statement of the rule was taken to be correct if it referred to the fact that the double function of matches in the presentation drawings had to be eliminated. This principle was sometimes expressed in terms of the statement used in the directions, "No match should be the side of more than one square." But any formulation implying "separateness" was accepted. Thus, "The squares in the answer have to be spread out" was also counted as correct. Between these two degrees of preciseness in verbalizing the rule many variations of expression were possible.

Only 21 per cent of the 233 students in the experiment were successful in correctly verbalizing the rule by this criterion. And since only 12 of the students of lower-than-average ability succeeded in so doing, it seemed inappropriate to analyze the results separately for the two classes of students. The percentage of all students in each of the nine treatment groups correctly stating the rule is given in Table 5.

When the measure of effectiveness of the information given as guidance during the instruction period was ability to verbalize the principle, only the amount of information given about the

TABLE 5

PERCENTAGE OF STUDENTS CORRECTLY VERBALIZING PRINCIPLE OF MATCH TASKS

Information About the Rule	Information About the Method			Totals Rule
	None	Some	Much	
Much	39	28	32	33
Some	11	11	28	17
None	29	04	07	13
Totals Method	27	15	22	21

Differences attributable to kind of information received

Kind of information	df	χ^2	χ^2 .05
Method information	2	3.7	6.0
Rule information	2	12.4	6.0
Method × rule information	4	6.7	9.5

Differences attributable to amount of information about the rule

Comparison	U	U.05
Much—no information	2.5	2.0
Much—some information	.6	2.0
Some—no information	.1	2.0

rule resulted in significant differences.

Neither the information which had been given as guidance to the method, nor the rule and method combinations produced reliably different levels of achievement.

The students who had had the most specific statement of the rule more often stated the rule correctly than those given a clue to the rule or given no information about the rule at all. Those given a clue to the rule were able to verbalize it no more often than those given no information at all.

While the amount of information given about the method did not make for significant differences in successful statements of the rule, the order of the three amounts of such information is

of some interest. Those students who receive no information about the method were most often able to state the rule, followed by those for whom highly directive method information had been the form of guidance. The students given only a clue to the method stated the rule least often. This order parallels that for information about the rule, where the criterion was success in solving the problems, for all students on the instruction problems, and for the "lows" on the simple and complex transfer problems.

A correct statement of the rule was not dependent on the student's prior success in solving the problems. For the total student group (both "lows" and "highs" combined) the following correlation coefficients were obtained:

Success on rule and instruction problems	.0
Success on rule and simple transfer problems	—.1
Success on rule and complex transfer problems	—.3

None of these correlations was significantly different from zero. (Correlations were between corresponding measures for total subgroups as described in Appendix A. The critical value of the coefficient equals .4.)

V. Interpretation of Results

A number of experiments have been reported in which seemingly less explicit clues proved more effective as guidance in problem solving than did more direct information, as, for example, information about the principle basic to solution. The superiority of the less explicit information in these situations has been attributed to the more active search demanded of the student, and to the possibility that, as a result of his more intensive search, the student would become cognizant of the structural relations obtaining to the problems.

An alternative explanation was offered which suggested that these experimental findings arose from a misdirection of the search. It was argued that information about principles and information about a method of attacking specific examples of a problem type may be two kinds of information, relating to two different subtasks. Guidance given to the discovery of the solution of one of these subtasks, it was suggested, might be inappropriate or even detrimental to the solution of the other, at least in the early stages of solving a problem.

It was predicted that where the criterion of success was appropriate to the kind of information which had been given as guidance, significant effects attributable to the proffering of that information would be discerned, but that where the information given and criterion were inappropriate, no such effects would be found. These predictions held for the present data. Only where the information given was consistent with the criterion used to determine success were significant differences revealed. On the other hand, information not in harmony with the criterion used proved no more efficient than no information at all.

The *Ss* were apparently presented with two tasks rather than one: (*a*) to discover a method of attack on the problems, and (*b*) to discover a satisfactory generalization of the principle. The kind of information given served to direct the search to one rather than the other of these tasks. And, since the more usual pattern in solving problems is first to discover a method of attacking the problem, information given about the principle would seem to introduce special difficulties for the problem solver. In any case, an active search may be assumed to have occurred whatever the kind of information made available to the student as guidance. The direction and focus of the student's search may have varied, however, depending on the kind of information he was given.

It was further hypothesized that there would be no significant difference in the effects of the two kinds of information for students of high and low intellectual ability. This null hypothesis was not substantiated. In the solution of both the instruction and transfer problems (simple and complex), the detrimental effects of having received an inappropriate kind of information appeared somewhat more marked for students of less than average ability. On the other hand, on the transfer problems, the differences attributable to having received an appropriate kind of information were more marked for these less able students. Apparently, for students of lesser ability, the power of information to direct or misdirect was greater than it was for the more able students.

This difference in the power of the information proffered to direct or misdirect may be explained as reflecting a greater ability of the more able students to integrate the two kinds of in-

formation and apply it to the solution of the problems. While no significant interaction was discerned either in the solution of the instruction problems or in the verbalization of the rule, such effects were present on the transfer problems. On the simple transfer problems, the students of greatest mental ability who had received a combination of information about the rule and method were superior, and on the complex transfer problems this superiority was maintained, although on these problems the differences found were not reliable. On the other hand, for the less able students, interaction was found significant only on the more complex tasks, and with these students it was precisely those who had received only information about the method, and no information about the rule, who were superior.

To suggest that information about principles and about methods of attacking a problem are two kinds of information does not imply that a combination of the two kinds of information cannot be understood and applied in problem solving. To derive a principle from an understanding of method, or to derive a method of attacking problems from an understanding of principle, and to integrate and apply the two understandings, would require more time than to discover either method or principle alone. Where the time allowed for problem solving is limited, students of highest mental ability might be expected to accomplish this integration more often than students of lesser ability. Given enough time, relatively easier examples, and greater success in solving the easier tasks, students of less-than-average ability might also be expected to benefit from receiving both kinds of information. But apparently these conditions did not obtain for the poorer students in their work with the match tasks.

It may be concluded that while information about principle and about method are two kinds of information, the effects of having received one rather than the other kind are more likely to be noted in the early stages of learning to solve a class of problems, and more likely to appear among poorer than among more able students. (And, though the experiment does not provide for this, it might be hypothesized that the effects are more likely to appear as the difficulty of the problem to be solved is increased.)

If information about method and about rule are accepted as two kinds of information, the test of the effectiveness of greater as against lesser amounts of information as guidance must be made where the criterion used to measure effectiveness is appropriate to the kind of information supplied. It was predicted that where an appropriate criterion was employed, the effectiveness of guidance would increase directly as the amount of information supplied the *S* increased. It was hypothesized that this relationship would hold both for students of greater and lesser mental ability.

Where the criterion was success in solving instructional and transfer problems, the predicted relationship between the amount of method information received as guidance and success was more characteristic of the students of greater ability, though it was not fully substantiated even among these students. On the instruction problems, it was true that the more method information the able students were supplied, the greater the percentage of the problems attempted and solved. This direct one-to-one relationship began to weaken on the simple transfer problems. On these tasks students who received information on the method were superior to those who had received no information, but the difference between the students who had received the greatest amount and those who had been given less explicit clues was not reliable. On the more complex transfer tasks, no reliable differences could be noted between the *Ss* receiving the three different amounts of information. Thus, while there appeared to be an initial advantage accruing to those receiving the greater amount of method information, as the more able students tried more of the problems, this initial advantage did not persist.

For the less able students advantages resulting from having been given highly directive information about method were even less marked. For these students, not only did the predicted relationship between amount of information about method and success in solving examples fail to appear, but, in fact, some evidence was secured to demonstrate that the less explicit form of guidance was preferable. On the complex transfer tasks, for example, only the *Ss* receiving the less explicit form of information were superior to those receiving no information at all. And since the more able students receiving the greatest amount of information as instruction failed to maintain their initial advantage, there is some support for the advocacy of those methods of guidance which require greater search and which lead to greater awareness of structural relationships.

But this interpretation is not entirely satisfactory. In the first place, the "awareness" or "structural" explanation does not make it clear why, if less explicit clues were beneficial for the less able students, such methods were not even more beneficial for students of greater than average ability. Second, if having given the students "some" information proved relatively more advantageous on the transfer problems than "much" information, and if this is explained by the greater search required, then why did not

the students receiving no information about the method do best of all? If a little search is a good thing, should not more search have been even a better thing? Third, why did those given the lesser amounts of information about the rule do less well in writing the rule? If search is helpful in and of itself, then similar benefits should have been exhibited on this task as well.

An alternative explanation of the results obtained in this study is possible. On the transfer tasks the principal differences were accounted for by the number of instruction problems attempted and solved correctly. For the complex tasks no reliable differences remained, attributable to the treatment variations, once the differences explained by prior performance on the simpler tasks had been taken into account. On the simple transfer tasks, in turn, no differences remained once variation in the percentage of instruction problems solved had been removed.

The advantage of having been given some guidance to the method was that it enabled the student to attempt and solve more of the initial problems in the limited time allowed. Whether the more or the less explicit form of guidance proved more effective depended upon the ability of the student to understand and apply the information given. The extent to which information was understood and utilized was not solely a function of the amount given. The better students were able to apply directly to the task at hand greater amounts of information. Less able students were less likely to comprehend the implications involved in the greater amounts of information, could less often apply it, and for these students, even on the initial problems, no differences appeared as between those given direct information and those given only a structural clue.

The fact that the more able students could make use of the more direct form of information may also explain the results obtained in stating the rule. On this task, students for whom the rule was identified succeeded more often than those given a clue to the rule, and these successful students were, with but a few exceptions, all drawn from the upper ability group.

Moreover, the differences in interaction for the two groups of students are also explained by the differences in their ability to make use of information given. Among the better students it was those given a combination of rule and method information who did best, but among the poorer students it was precisely the groups given information about the method, and none about the rule, who did best on the transfer tasks.

As the students moved from the instruction problems to the simple transfer tasks and then to the more complex tasks, the differences resulting from their having had a certain type of guidance rather than another became less marked. This was true both for the more and less able students, but more especially for those of greatest ability. This suggests that the beneficial effects of guidance lie in the speed with which the student is brought to his best level of performance. Understanding, to the level of the *S*'s ability, is likely to be achieved irrespective of the kind and amount of guidance offered. If the guidance is appropriate, and if the student is able to make use of the greater amounts of information, he will be helped to attain his maximum level most quickly by being given more direct forms of aid. But if the direct instructions cannot be applied by the student, less direct forms of instruction may prove just as beneficial.

The present study has dealt with the solution of intellectual problems. On the basis of the results obtained it might be argued, but by analogy only, that in the guidance of emotional problems the efficacy of nondirective guidance may result from the inability of the *S* to apply specifically directive information to what are, for the *S*s, extremely difficult problems.

The ability to verbalize a principle without, at the same time, a corresponding ability to apply the principle to the solution of problems, is not generally accepted as a satisfactory outcome of guidance. With this in mind, the results of the present experiment carry certain implications for guidance in situations similar to those experimented with here.

The learning situation used was characterized by the following conditions: 1, students were engaged in intellectual problem solving—they had to discover the solution for themselves; 2, the problem was one in which previously acquired generalizations could not be readily applied; 3, the principle underlying the problem was not a formula in the sense that it prescribed specific steps needed to solve any given variation of the problem; and 4, the time given to instruction and problem solving was restricted.

In situations meeting these conditions, the results of the study suggest:

1. Information given the student about the method of solving examples is more likely to be beneficial than information given about the principle—at least in the initial stages of problem solving.

2. Some appropriate guidance will prove more helpful to the student than no guidance. Leaving the student to discover for himself the solution of a problem will not prevent understanding, but will probably delay it.

3. The effectiveness of guidance does not depend solely on the amount of information imparted. More explicit forms of instruction will prove most helpful with students able to apply

the information. For students of lesser ability, less explicit clues, designed to highlight structural relationships, may prove just as effective.

VI. Summary

An unresolved issue in the guidance of problem solving is the desirability of making available greater rather than lesser amounts of information. Information may be of two kinds; it may relate either to the principle or to method. It was hypothesized that performance would improve as the amount of information given as guidance about method of solution or principle for solution was increased.

Several forms of the match task were presented to twelfth grade students. In guidance there were three variations in the amount of verbal information given about the principle: "No information"; "Some information," a clue to the principle; and "Much information," a statement of the principle. Similarly, students were given "No," "Some," and "Much" information about the method of solving examples. The combination of the amounts of information about method and principle yielded nine different instruction treatments ranging from one with no information about either the principle or the method, to one with highly directive information about both principle and method. Success was appraised in the number of instructional tasks solved, in transfer to simple and complex problems, and in verbalizing the principle separately for students above and below average in mental ability.

For students above average in mental ability, success in solving problems increased only for the instruction problems directly as the amount of information given about method increased. For students of lower ability, some appropriate guidance was superior to no guidance. In solving the problems both for students above and below average in mental ability, information about the rule did not seem to affect results differentially.

For the simple transfer problems, the more capable students seemed to profit most from the combination of explicit information about the rule with an indirect clue to the method, or from a clue to the rule in combination with explicit information about method. On the complex transfer tasks, the high ability students receiving only information about the method, or only an indirect clue to the rule, did less well than students given other combinations of information. But on these complex tasks, students of less than average ability given only guidance to the method, in either the direct or less explicit form, were superior.

No treatment effects remained for the complex transfer problems once an adjustment had been made for differences on the simple transfer tasks. Similarly, for the high ability group, at least, no treatment effects remained on the simple transfer problems once scores were adjusted for differences in success on the instruction problems.

Success in writing the rule increased as the amount of information students had been given about the rule increased, although only the students given the most explicit information about the rule were superior to those given no information about the rule. In writing the rule, no effects were noticed which could be attributed to the amount of information the students had received about the method of solving examples. Success in verbalizing the rule was uncorrelated with success in solving the problems.

These results were interpreted to indicate (*a*) that information used in guidance must be appropriate to the task set for the student, (*b*) that some appro-

priate guidance is beneficial, but that failure to provide it will delay rather than prevent solution, (*c*) that the effectiveness of guidance does not depend solely on the amount of information imparted, but that (*d*) more explicit instruction will prove most helpful with the more able students while (*e*) less explicit instruction may be just as effective as more directive guidance for the less able students.

Appendix A

STATISTICAL PROCEDURES

The analyses of variance reported in the text, with the exception of the analysis of mental ability means, were carried through on ranked measures. In this way, the assumptions of normality of score distributions and of homogeneity of treatment variances were avoided—assumptions which in most cases were untenable. It is interesting to note that the practical difference of this use of distribution-free statistics was not great. As a check, all of the analyses were carried through in the more traditional manner in disregard of the assumptions. Except for a few instances in which the nonparametric test statistic proved to be very close to its critical value, the decisions reached were identical under either procedure. However, the distribution-free tests described below were the techniques of choice for the present data.

For each of the nine treatments, and for both the "Highs" and "Lows," three subgroups were formed. This was done by assigning students to the subgroups, in order, from a list of the ranked mental ability scores for each treatment. For example, for the treatment: "No information on rule; no information on method," the subgrouping was as follows:

Otis Score	*Subgroup*
69	1
60	2
54	3
54	1
54	2
53	3
.	.
46	1

Students in the other treatment groups were assigned to subgroups in a like manner. The composition of the subgroups remained constant for all of the analyses, of course.

The next step was to compute means (or, in some cases, percentages) for each of the subgroups on the particular measure being studied. To test the main effects of the three variations in information about the method, the variations in information about the rule were treated as replications, with comparable subgroups ranked. To test the main effects of the variations in information received about the rule, the process was reversed, and the comparable subgroups on method were treated as replications. The test itself consisted in determining the probability of the obtained rank totals for, first, the three variations in method information, and then for the three variations in rule information. The formula used and the test is more fully described by Moses (15) and Freidman (7).

To test the significance of the interaction, Rule $\times$ Method, the procedure suggested by Wilcoxon (24) was employed. The test statistic was computed as a sum of two values. One component was obtained by tabulating the differences between corresponding subgroup values for the "Much" and "Some" rule variations for each of three variations in method information. The second component was obtained by finding the difference between the sum of the values of the "Much" and "Some" rule variations and twice the value of the "None" rule variation for comparable subgroups—again, for each of the three method variations. These differences were then ranked and the test described above was applied to the rank totals. The argument for the procedure is that, assuming there is an advantage accruing from having received a particular combination of rule and method information, the differences will be consistently greater (or smaller) for each of the replications of the treatments so devised.

In those cases where the main effects were shown to be significant by the procedure described above, the Mann-Whitney (11) "*U*" test was used to analyze the difference between individual means of the variations. The test is well known and does not need to be described, but it needs to be pointed out that the individual comparisons were made by ranking the eighteen subgroup means for any two variations under consideration.

Finally, it should be noted that correlations and tests for linearity, which are reported in the text, were also based on the subgroup estimates on the measures of interest.

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